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DESCRIPTION OF MICROWAVE SYSTEM ACCEPTANCE TESTS

December, 1953

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DESCRIPTION OF MICROWAVE SYSTEM ACCEPTANCE TESTS

INTRODUCTION

This memorandum will describe the final acceptance tests conducted with respect to equipment in Divisions 1, 2, and 3 of the microwave system described i [redacted] report entitled "General Description of Requirements for a Microwave System" dated March, 1952. As a result of these tests, it has been concluded that the radio equipment in these divisions has been properly installed and adjusted by [redacted] and should be accepted by the customer. No consideration has been given as yet to the acceptability of instruction books since these have not yet been delivered. 25X1 25X1

Arrangements for the final acceptance tests were made at a conference held in October attended by representatives of the customer, [redacted] Recognition was given to the fact that the installation of this equipment has extended over a period of 6 to 10 months and that close supervision of the installation and operation of equipment has been maintained by representatives of the customer during that time. It was agreed that sufficient experience had been gained with the system during the installation period to conclude that basically the system has been installed in accordance with good engineering practice. Accordingly, a decision was made that primary emphasis in the final acceptance tests should be upon performance. It was agreed that two types of performance tests should be made: 25X1

(1) A determination of the overall performance characteristics of the system, and

(2) a determination that equipment [redacted] 25X1
[redacted] is operating properly. 25X1

Acceptance tests were concluded on October 30, 1953.

GENERAL NATURE OF TESTS

System performance tests: - Experience gained during installation of the system had indicated that there was no reason to expect that the system would not meet and surpass performance requirements. Preliminary tests made prior to formal acceptance tests indicated further that satisfactory performance would be obtained if systems tests were made on a looped circuit basis rather than by a check of each circuit separately. This being the case, it was decided to conduct overall circuit performance tests insofar as possible at [redacted] by transmitting a test signal out from that [redacted] on one channel and receiving it back on a second channel patched to the first channel at a [redacted] at the far end of a microwave path. This procedure turned out to be completely feasible with respect to voice circuit tests, and all measurements of overall circuit performance on voice channels were made from [redacted] 25X1 25X1 25X1 25X1

With respect to the teletype circuits, it was found desirable to supplement the looped circuit type of test described above with tests conducted on a single circuit basis with personnel at both ends of a path. The path chosen for this and considered typical of all paths was that between [redacted] The reason for the supplemental tests was to analyze more closely than is possible on a looped circuit basis, the manner and extent to which distortion may be expected to 25X1 accumulate on a teletype circuit which is patched a number of times.

Equipment performance tests: - The equipment performance tests were made on [redacted]. The tests conducted were designed to ascertain whether or not the various components were operating properly and reliably and that the reflectors and antenna systems were properly aligned. The principal test made at each station was a determination of the relative value of the received radio frequency signal. This was accomplished by inserting a calibrated IF strip in each receiver and reading the output on the appropriate meter. In addition, a check was made of the readings of all metered circuits and of the adjustments of tuning controls. 25X1

RESULTS OF OVERALL SYSTEMS PERFORMANCE TESTS

The results of the systems performance tests are tabulated in Appendix I for voice circuits, and in Appendix II for teletype circuits. The nature of the tests of the voice circuits and the results will be described first and then there will follow a description of the teletype circuit tests and the results.

The voice circuit tests were conducted using the 1000 cycle test signal source provided with the microwave equipment. This signal was applied to each circuit under test at a level of 0 dbm. The output of the circuit was taken from a voice terminal chassis, passed through a 300-3500 cycle band pass filter, and measured using a Hewlett-Packard Voltmeter across a 500 ohm load. The output signal was also viewed on an oscilloscope and observed for flattening and limiting as the input signal was increased. The signal measured for 0 dbm input was compared with noise measurements made in the same manner without the presence of any input signal. The results of these tests indicate that the loss of signal at a voice patch may be expected to be approximately 1 db and that a S/N ratio of approximately 45 db or better may be expected on all voice circuits.

Tests of cross-talk were conducted by listening on one channel while the test signal was inserted at one and all of the other channels. No appreciable change in performance resulted from adjacent channel operation. Increases in noise level of 1 db and 3 db were noted on a receiving channel for insertion of tone on 1 adjacent channel and on all other channels respectively.

A check was made of the effect of operating one sub-carrier channel alone as compared with having all sub-carrier channels in operation simultaneously. It was found that there is negligible effect in performance with variation in sub-carrier loading. A decrease of 1/2 db in received signal strength and a decrease of 2 db in noise level was measured on a given channel with no other channel on, as compared with all channels on.

The teletype tests showed considerably more variation between circuits than was found in the case of voice circuits. The tests of teletype circuits were made using normal teletype machines. For all tests, a series of RY letter combinations were sent by tape from one machine and received by a second machine. As a measure of performance, a determination was made for each circuit of the effect of the circuit upon the range over which a receiving machine could be adjusted and still

[redacted] 25X1

provide solid copy.

For a good teletype signal it should be possible to obtain satisfactory copy over a range of 80 on the range adjustment. Anything which effectively distorts a teletype pulse reduces the range over which the machine will operate. While a machine may be adjusted to compensate for such distortion, it is desirable to have the operating range as broad as possible so as to permit satisfactory operation in spite of variations in received signal. The variations may result from variations in transmission characteristics or variations resulting from use of different transmitting teletype machines.

The first teletype tests were made on a looped circuit basis from [redacted] in the same manner as the voice circuit tests were made. 25X1 However, in making loop-circuit tests of teletype circuit performance, it was found that some looped circuits caused considerably more reduction in range than others. To evaluate the reasons for the relatively large variation in distortion, or loss of range, caused by the radio circuits, tests were made over a single path with personnel at both ends. The path between [redacted] was chosen for these tests. 25X1 Teletype machines at both ends were used to transmit to each other so that measurements could be made in both directions using two different machines. In addition, circuits were patched at [redacted] to determine 25X1 the effect of adding circuits by patching.

In the tests between [redacted] it was found that 25X1 while a relatively large variation existed from circuit to circuit in each direction, all circuits worked well and with a range adjustment no lower than 45. Two-thirds of the circuits provided range values of 60 or better. No problem was anticipated with respect to one circuit transmissions. The problem which remained was the effect of patching circuits and particularly the effect of patching circuits having low range values as compared with patching circuits having high range values.

Tests were made of the effect of patching various types of circuits to see in what manner distortion effects accumulate. It was found that by patching circuits having high range values, very satisfactory results can be obtained even with a multiplicity of patched circuits. However, with circuits having relatively low range values, it can be expected that the range will drop to 0 with only 2 or 3 patches unless care is taken to insure that the particular circuits in a path have distortion effects which are compensatory.

As an overall result of considerable testing, it was found possible to make up to seven patches including circuits in all three divisions (Div. 1, Div. 2 and Div. 3) using circuits each of which has a range of 65 or better when measured on a single circuit basis. A maximum of six patches were made when one loop circuit having a range of 45 was used in place of a loop circuit having a range of 65 or better. In general, it was found that circuits of average characteristics can be patched from one station in the system to any other. However, some circuits may or may not work in an extended multiple patch condition depending upon whether the distortion effects in a particular combination of circuits tend to compensate or not. With good circuits, the extent of patching which is reasonable depends principally upon how much decrease in range can be accepted in practice.

The effect of changing tubes and relays in the teletype (audio frequency carrier) equipment was studied to ascertain the reason for variations in teletype circuit performance. It was found that by interchanging tubes and relays, considerable improvement could be realized in any particular circuit. It was concluded that the variations observed in the tests were the result of the cumulative effects of the characteristics of tubes and relays in a particular circuit. It was recognized in this respect that many of the teletype circuits had been installed and in an operating condition although not actually used for a considerable period of time. It was felt that the condition of the circuits may be attributed to a lack of use and a lack of routine maintenance during the period since installation. It was felt that inasmuch as the circuits in their present condition will provide satisfactory operation, no serious attempt should be made at this time to improve the performance of the poorer circuits. It is felt that with routine maintenance and regular use, all circuits can be brought to a standard of performance at least as high as that of the average circuit tested.

RESULTS OF EQUIPMENT PERFORMANCE TESTS

The results of the equipment performance tests are tabulated in Appendix III. In addition to those values shown, a check was made at the time of inspection of each station of the values of other metered circuits and of the adjustment of tuning controls.

The most significant test made in conjunction with the equipment performance tests was a determination of the value of received signal strength at each station. This test was made by inserting a calibrated IF strip in place of the regular strip in each receiver at each station. With the calibrated strip in operation a reading was made of the values of input signal to the fifth and seventh IF stages and the first limiter stage. While the value of the reading is dependent upon propagation conditions as well as antenna alignment, and RF tuning characteristics, it was felt that this test would provide a reasonably good indication of whether or not the RF equipment in a particular path is working properly and providing a satisfactory signal. A comparison of the readings made at all stations as tabulated in Appendix III indicates that all stations were operating with strong received signals. One path, that between C and D was noted to have a lower received signal strength than would reasonably be expected when it is compared with other paths. The reason for the lower received signal is the fact that one antenna reflector in this path had been only partially aligned at the time of the tests. This path has since been fully aligned with a resulting increase in signal strength. It is estimated from the tests of RF received signal strength that all paths are operating satisfactorily with at least 28 db of safety factor to provide for fading.

Other tests made during the inspection of equipment performance involved the readings of meters and checking of tuning adjustments and the AFC (automatic frequency control). The values of limiter currents at the sub-carrier receivers are tabulated in the Appendix. All of these values were found to be within the proper order of magnitude with the exception of one circuit. In the case of this circuit the manufacturer

[redacted] 25X1

had ordered and planned to replace a sub-carrier transmitter. The particular sub-carrier transmitter in question is that for voice channel 3 at Station O.

Miscellaneous checks made during the inspection of equipment performance resulted in satisfactory results indicating normal and stable operation of all components.

CONCLUSIONS

It may be concluded that the microwave system as installed by [redacted] for Divisions 1, 2, and 3 is operating in a satisfactory manner and should, therefore, be accepted by the customer with the exception of instruction books which have not yet been delivered. It is further concluded that if the system is to continue operating in a satisfactory manner, routine maintenance must be conducted on a regular basis. In addition, the circuits in this system should be exercised by frequent use. 25X1

Respectfully submitted,

[redacted] 25X1

December 10, 1953
Appendices

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APPENDIX I - SUMMARY OF DATA ON VOICE CIRCUITS

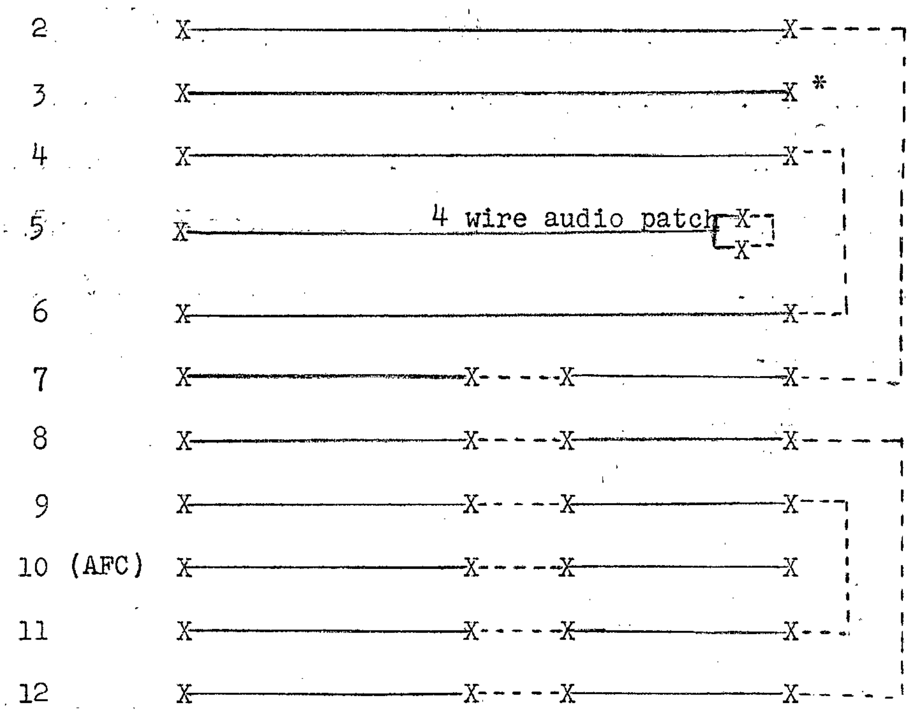
A. Diagrams showing patching arrangement

The patching arrangements shown below were used for all tests [redacted]. All circuits were patched on a two-wire basis unless shown otherwise. 25X1

Division 1:

Voice Channel # [redacted] 25X1

1 (AFC) This circuit used for teletype



*Sub-carrier transmitter to be replaced by Motorola.

- - - Dotted lines indicate audio patch

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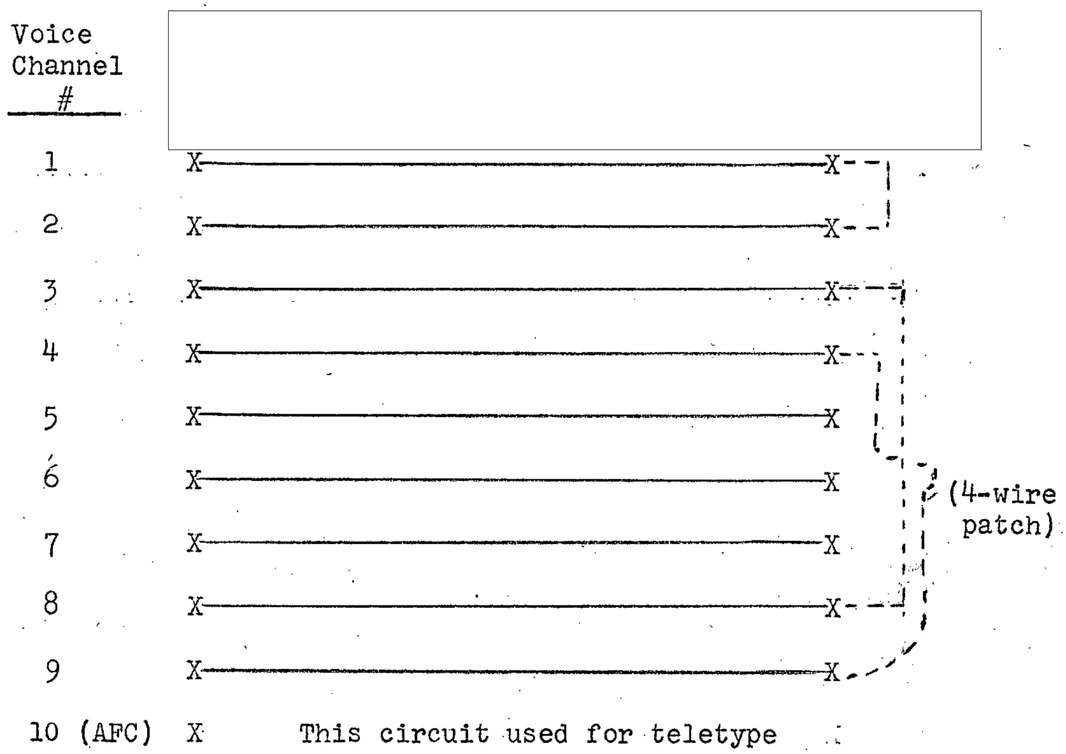
APPENDIX I - (Continued)

A. Diagrams showing patching arrangement (continued)

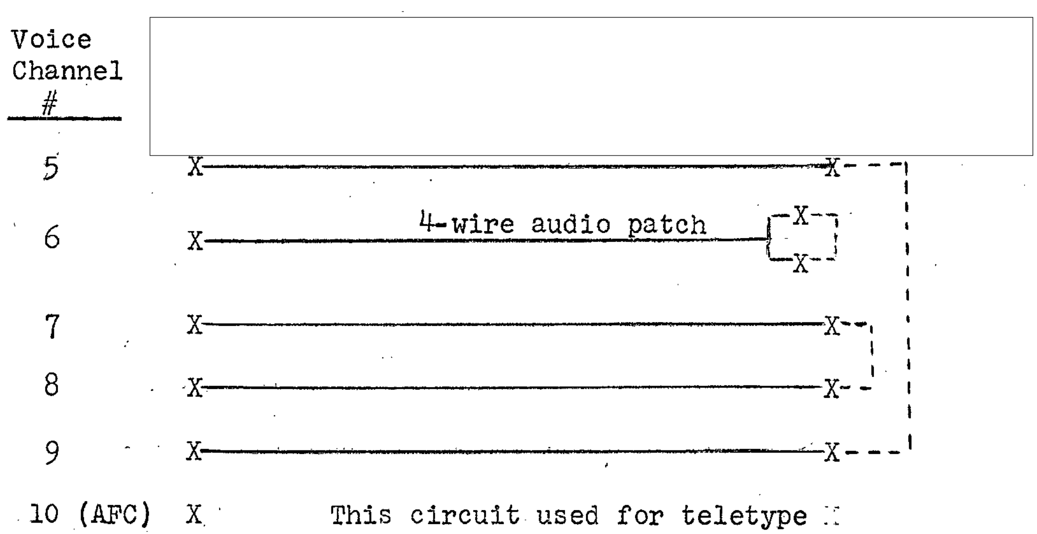
Division 2:

25X1



Division 3:

25X1



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APPENDIX I (Continued)

B. Voice circuit performance tests - On-channel performance

All tests were made using a 1000 cycle test tone input signal of 0 dbm and measured at the output of a voice terminal on a two-wire basis across a 500 ohm load resistor. A 300-3500 band pass filter was inserted between the output of the band pass filter and the 500 ohm load. Observation of flattening and limiting of the output signal was made on an oscilloscope as the input signal was increased to the values shown in the extreme right hand column of the tables below.

Division 1:

Input at (ch)	Output at (ch)	# of voice patchs	# of RF paths	Signal output for 0 dbm input	Noise output for no input	Signal / Noise	Signal input for perceptible flattening of output signal (dbm)
2	7	2 2-wire	4	-2 dbm	-49 dbm	47 db	+10 limiting
7	2	2 2-wire	4	-2 dbm	-45 dbm	43 db	+ 9 limiting
4	6	1 2-wire	4	0 dbm	-47 dbm	47 db	#11 limiting
6	4	1 2-wire	4	0 dbm	-47 dbm	47 db	#4 flattening +11 limiting
8	12	3 2-wire	4	-3.5 dbm	-52.5 dbm	49 db	+10 limiting
12	8	3 2-wire	4	-4 dbm	-54 dbm	50 db	+ 3 flattening + 8 limiting
9	11	3 2-wire	4	-4 dbm	-58 dbm	54 db	+ 6 flattening + 9 limiting
11	9	3 2-wire	4	-5 dbm	-48 dbm	43 db	+ 6 limiting
5	5	1 4-wire	4	+3 dbm	-37 dbm	40 db	+ 5 flattening +11 limiting

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APPENDIX I (Continued)

B. Voice circuit performance tests - On-channel performance (continued)

Division 2:

Input at (ch)	Output at (ch)	# of voice patchs	# of RF paths	Signal output for 0 dbm input	Noise output for no input	Signal / Noise	Signal input for perceptible flattening of signal (dbm)
1	2	1 2-wire	4	-2 dbm	-48 dbm	46 db	+6 flattening +8 limiting
2	1	1 2-wire	4	-2 dbm	-48 dbm	46 db	+6 flattening +8 limiting
3	8	1 2-wire	4	-2 dbm	-56 dbm	54 db	+3 flattening +9 limiting
8	3	1 2-wire	4	-2.5 dbm	-51 dbm	48.5db	+5 flattening +9 limiting
4	9	1 4-wire	4	-1 dbm	-46 dbm	45 db	+4 flattening +9 limiting
9	4	1 4-wire	4	-2 dbm	-46 dbm	44 db	
5	7		No signal				
7	5	1 2-wire	4	$+\frac{1}{2}$ dbm	-44 dbm	44 db	+4 flattening +7 limiting

APPENDIX I (Continued)

B. Voice circuit performance tests - On-channel performance (continued)

Division 3:

Input at (ch)	Output at (ch)	# of voice patchs	# of RF paths	Signal output for 0 dbm input	Noise output for no input	Signal/Noise	Signal input for perceptible flattening of signal (dbm)
5	9	1 2-wire	4	-2 dbm	-60 dbm	58 db	+3 flattening +7 limiting
9	5	1 2-wire	4	-1 dbm	-59 dbm	58 db	+3 flattening +8 limiting
7	8	1 2-wire	4	-2 dbm	-61 dbm	59 db	+5 flattening +11 limiting
8	7	1 2-wire	4	0	-50 dbm	50 db	+3 flattening +6 limiting
6	6	1 4-wire	4	+7 dbm (set for teletype at J)			+3 flattening +9 limiting

APPENDIX I (Continued)

C. Voice circuit performance tests - cross-talk

For these tests, the effect of adjacent channel operation was determined by observing the effect on the noise output on a desired channel as a signal was applied to adjacent channels.

Division 1:

Signal in at adjacent channel #	Noise measured at channel #	Effect on noise on the receiving channel
3	7	1 db increase in noise on channel 7 as tone is applied to channel 3.
3	6	No change in noise on channel 6 as tone is applied to channel 3.
3, 4, 5, 6, 11, and 12	7	Without tone: -47 dbm With tone: -44 dbm

Division 2:

Signal in at adjacent channel #	Noise measured at channel #	Effect on noise on the receiving channel
1, 2, 3, 5, 6, 7, and 8	4	Without tone: -47 dbm With tone: -50 dbm

Division 3:

Signal in at adjacent channel #	Noise measured at channel #	Effect on noise on the receiving channel
5, 6, and 9	7	Without tone: -50 dbm With tone: -55 dbm

[redacted] 25X1

APPENDIX I (Continued)

D. Voice circuit performance tests - load checks

The following tests were made to determine the effect of channel loading. The tests were made only with respect to Division 1 on the assumption that this would be the division most affected by load variations since it has the largest number of channels. Two tests were made, one to determine the effect on the noise level on a particular channel as other channels are placed in use. The other check to determine the effect on circuit performance as other channels are placed in use. For both checks, output was measured on channel 6 at [redacted] For the circuit performance check a tone was inserted at channel 4, [redacted] which circuit is patched at [redacted] to channel 6 and transmitted back t[redacted] over this latter channel. 25X1 25X1 25X1 25X1

Effect on circuit noise of channel loading:

Noise output on channel 6 with all other voice channels at [redacted] turned off 25X1	-48 dbm
Noise output on channel 6 with all sub-carrier transmitters at [redacted] turned on 25X1	-46 dbm

Effect on circuit performance of channel loading:

Output of channel 6 for an input tone of 0 dbm at channel 4 with all other voice transmitters at [redacted] [redacted] turned off 25X1 25X1	1.5 dbm
Output of channel 6 for an input tone of 0 dbm at channel 4 with all other voice transmitters at [redacted] [redacted] turned on [redacted] 25X1 25X1	1 dbm

APPENDIX I (Continued)

E. Ringing and qualitative checks

All circuits were checked for ringing and talking from the patch board. The results were as follows:

Division 1:

Channel #:	to	:Channel #:	Comment
2		7	Ringing O.K. in both directions.
4		6	Ringing O.K. in both directions.
5		5	No ringing possible on 4-wire circuit.
8		12	Ringing O.K. in both directions.
9		11	Ringing O.K. 9 to 11, but no ringing 11 to 9*.

Division 2:

Channel #:	to	:Channel #:	Comment
1		2	Ringing O.K. in both directions.
3		8	Ringing O.K. in both directions.
4		9	Ringing O.K. in both directions.
5		7	Ringing O.K. 7 to 5, but no ringing 5 to 7*.

Division 3:

Channel #:	to	:Channel #:	Comment
5		9	Ringing O.K. in both directions.
7		8	Ringing O.K. in both directions.

*Ringing on these circuits is considered to be a matter of minor adjustment.

APPENDIX II - SUMMARY OF DATA ON TELETYPE TESTS

A. Teletype circuit performance tests - local loop tests

The following data indicates the range readings obtained when a teletype tape was used to operate a teletype machine by transmitting through an audio frequency carrier transmitter feeding directly into an audio frequency carrier receiver at the same station without being transmitted over a radio path. The readings in parenthesis show the limiting values of range adjustment from which the range reading for each circuit was determined.

Channel #	Division 1 Circuit A	Division 1 Circuit J	Division 2	Division 3
18	80 (95-15)	80 (95-15)	80 (100-20)	70 (90-20)
17	75 (95-20)	70 (100-30)	70 (95-15)	75 (95-20)
16	60 (98-38)	65 (105-40)	75 (105-30)	85 (105-20)
15	68 (98-30)	75 (95-20)	70 (105-35)	80 (100-20)
14	67 (95-28)	60 (95-35)	65 (85-20)	80 (100-20)
13	65 (95-30)	60 (105-45)	80 (100-20)	70 (95-25)
12	80 (96-16)	70 (100-30)	65 (100-35)	70 (90-20)
11	60 (90-30)	65 (100-35)	70 (100-30)	80 (100-20)
10	64 (96-32)	70 (100-30)	70 (100-30)	80 (105-25)
9	74 (98-24)	70 (95-25)	80 (100-20)	75 (105-30)
8	72 (90-18)	70 (100-30)	No equipment	80 (105-25)
7	72 (90-18)	65 (95-30)	No equipment	80 (105-25)
6			No equipment	70 (95-25)
5			No equipment	75 (100-25)

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APPENDIX II (Continued)

B. Teletype circuit performance tests - remote looped circuits

The following data shows the range values obtained when circuits were looped remotely, that is patched at DC, at the far end of a radio path. For these tests, a teletype signal was inserted from a tape at [redacted] and received on a teletype machine also at [redacted]. Each circuit includes the same numbered channel in each direction. That is, looped circuit #18 consists of circuit 18 from [redacted] patched at far end to circuit 18 back to [redacted] 25X1 25X1 25X1 25X1

Looped teletype circuit #	Division 1 circuits patched at O	Division 2 circuits patched at K	Division 3 circuits patched at J
18	70 (80-10)		
17		50 (100-50)	
16	40 (95-55)		
15		55 (95-40)	
14	60 (96-36)		
12	55 (86-31)		62 (82-20)
		30 (85-55)	70 (91-21)
10	57 (92-35)	47 (84-37)	50 (90-40)
9			45 (90-45)
8	48 (86-38)		65 (95-30)
7			45 (85-40)
6			35 (82-47)
5			52 (82-30)

APPENDIX II (Continued)

C. Teletype circuit performance tests - Supplemental tests to study effect of multiple patching

(a) Listed below are the range values obtained on a single circuit basis between [redacted] The local loop machine range of the teletype machine at [redacted] measured 80. The local loop machine range at [redacted] measured 75. 25X1 25X1 25X1

Teletype circuit #	Range of circuits from D to K	Range of circuits from K to D
18	65 (105-40)	60 (105-45)
17	75 (105-30)	45 (100-55)
16	55 (105-50)	75 (105-30)
15	50 (105-55)	80 (105-25)
14	Channel in use	
13	55 (100-45)	75 (105-30)
12	65 (100-35)	50 (95-45)
11	50 (95-45)	70 (100-30)
10	60 (100-40)	60 (95-35)
9	65 (105-40)	65 (100-35)

[redacted] 25X1

APPENDIX II (Continued)

C. Teletype circuit performance tests - Supplemental tests to study effect of multiple patching. (continued)

(b) Listed below are the ranges obtained when circuits were multiple patched. The circuit arrangements are shown with the originating station letter first followed by the circuit number from that station, followed by the letter of the receiving station, followed by the symbol () to indicate a patch, followed by the circuit number from that station, the letter of the next station, etc.

Test #	Circuit arrangement	Range value	Number of patchs	Comment	
1.	[redacted]	55	1	Patching 2 best circuits for sending and receiving at [redacted]	25X1 25X1
2.		75	1	Patching 2 best circuits for sending and receiving at [redacted]	25X1
3.		5	1	Patching 2 worst circuits for sending and receiving at [redacted]	25X1
4.		25	1	Patching 2 worst circuits for sending and receiving at [redacted]	25X1
5.		50	2	Patching 3 best circuits	
6.		55	3	Patching 4 best circuits	
7.		15	4	Patching 5 best circuits	

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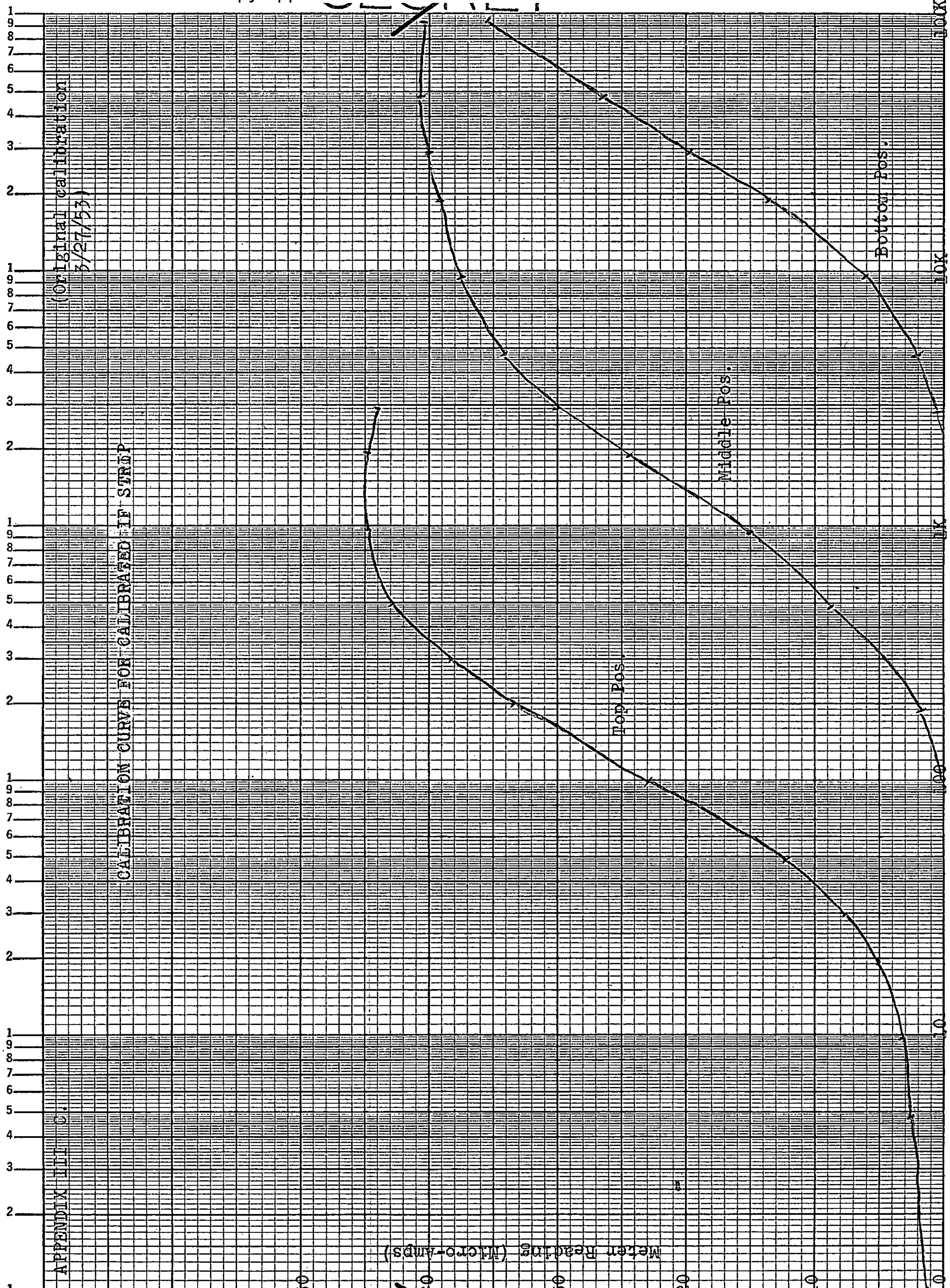
APPENDIX III C.
CALIBRATION CURVE FOR CALIBRATED IF STRIP
(Original calibration 3/27/53)
Bottom Pos.
Middle Pos.
Top Pos.
Meter Reading (Micro-Amps)
0
10
20
30
40
50
10
100
1K
10K
100K